Teaching Science to Students with Learning and Other Disabilities: A Review of Topics and Subtopics Appearing in Experimental Research 1991-2015

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Abstract

This article reviews 24 years of research focused on science education for students with learning and other disabilities. Our results are based on 53 articles from 2 relevant databases. We hereby present and discuss the results of the most popular topics investigated, which include: constructivism, exploratory learning, hands-on activities, cross-curricular projects, multiple means of representation, cognitive and social skills, group and peer learning, coursebooks, reading strategies, readability and students' assessment. Our results suggest that topics like teacher education, teacher/researcher co-operation, education policy, school administration and curriculum structure are scatteredly investigated. These experimental approaches and interventions may provide insight into teacher training in higher education and can explain controversial concepts regarding the question of "full inclusion, selective inclusion or excellency".

Keywords: Students with disabilities, Learning disabilities, Review, Science instruction

1. Introduction

For many years, science education for students with learning disabilities, mild mental retardation or emotional disturbances, behavioral disorders and hearing or vision impairment has been the topic of intense investigation within the research community. Research has focused on educational means and materials used during instruction, teaching methods, models and practices, curriculum structure, teachers' education, etc. The systematic presentation in this paper of the topics and subtopics that have been investigated will help the university community generate effective teachers' education programs that could focus on teaching practices which have been extensively studied. This paper could also inform researchers about issues that have not been extensively investigated and assist those who formulate education policy to create the conditions for successful integration of children with special educational needs at school.

2. Method

Research papers included in this study were selected from 2 relevant databases: ERIC database and a newly formed database on pedagogical journals at the University of Thessaly in Greece. The university database is designed so that it can be used during teacher training programs; special education teachers already use this database as a resource for their pre-service practicum and their essays. Current study is based on the analysis of 53 articles (see Table 1 and Table 2) which reported empirical studies on science education for students with learning and other disabilities.

The articles used in this study were published in 39 international journals of education the past 24 years. We have set

1991 as a *terminus post quem*, as the Department of Special Education at the University of Thessaly in Greece has included papers published since 1991in its database. The majority of the articles used in this study were published to the following journals: *Remedial and Special Education*, *The Journal of Special Education*, *Learning Disability Quarterly* and *Journal of Learning Disabilities*. Studies included students from all different age groups, from elementary to high school (4th grade to 11th grade) of the North American/Anglo-Saxon school system. Research studies were mainly focused on 4th, 5th, 7th and 8th grade students; so, our findings could be more useful for teacher candidates who will teach at relevant grades. Students' population used in those studies varies from a few students (e.g. 2, 3, or 7) in case studies, to numerous groups of students (e.g. 8000 or 9850 students) in large scale surveys. Number of teachers participating in those studies varies from very few (3 or 4) in case studies to 61 or 73 in large-scale surveys, correspondingly. Groups with varying number of students between the two ends are also included in the studies (e.g. 10, 21, 29, 40, 45, 60, 69, 107, 154, 241, 271, 624, 836, etc.). Demographic data from the students participating in those studies included age, gender, ethnicity (Caucasian, African-American, Hispanic-American, Asian, etc.), family status (single parent family, divorced parents etc), income status (low income, high income) etc.

Only studies providing a clear identification of a student as a student with learning or other difficulties were included in this review. Participating students had been identified as students with learning or other difficulties based on IQ tests, reading or other standard tests, inappropriate behavior or whether an Individual Education Plan had been developed for the student. Studies in which participating students have been diagnosed with dyslexia, or having hearing and vision impairments were also included. The specific students participated in general education classes where a special educator was or was not present. Studies referring generally to "low achievers" were not taken into account.

We reviewed empirical investigations concerning science education. The term "science" includes several subjects that fall into different categories based on their content. The subjects that present the higher frequencies in these 53 investigations are: physics (19), chemistry (9), biology (9), environmental studies/ecology (6), geology (5), astronomy (3), engineering (3), technology (2), zoology (1), and phytology (1). Certain researches refer to more than one science subjects, while others combine science with different content areas, such as mathematics.

Recently published review articles focusing on science education for students with disabilities and on several means of instruction (e.g. graphic organizers) reinforce our approach (Scruggs et al., 1998; Scruggs et al., 2010; Matkins & Brigham, 1999; Dexter et al. 2011; Therrien et al., 2011). The previous reviews focus on summarizing conclusions of the studies as well as acknowledging the best teaching practices. Our paper aims at revealing the topics and subtopics on which researchers have focused from a different perspective, regardless of whether these issues have been proven fruitful for teaching. We recorded general topics and their subtopics (e.g. constructivism: exploratory learning, hands-on activities, cross-curricular projects, etc.) even if they appeared as a theme in the research procedure only once. We note that several studies look into more than one topic, while in some cases different topics are examined simultaneously (for example, peer-teaching or cognitive development is frequently investigated as an essential part of exploratory learning). In our study, the most popular topics investigated in the selected literature will be presented in descending order of frequency so that research community is informed about the issues which are scatteredly investigated and so that policy makers plan the successful integration of students with special educational needs in general education.

3. Results

3.1 Constructivism, Exploratory Learning, Hands-On Activities, Cross-Curricular Projects

In the context of constructivism (see Table 1) researchers use *discovery* or *inquiry learning* in order to develop and improve cognitive skills. To this end, they apply specific techniques and approaches –such as *problem-based learning*, *hands-on activities*, exploring children's conceptions and misconceptions.

Constructivism helps students actively acquire a cognitive structure; it enhances integration of information into an existing cognitive scheme, meta-cognitive skills and the refinement of cognitive structures. Through this perspective several studies focus on the investigation of a) exploratory learning as opposed to traditional instruction and b) the ability to maintain the acquired knowledge after a certain period of time. It is noteworthy, that although traditional and direct instruction are widely used in everyday practice, researchers are interested in it mainly compared to exploratory learning and inquiry based instruction, (Scruggs et al., 2010). The conclusion is that inquiry based instruction helps students improve their conceptual understanding, including the usage of data and information, retaining of cognitive skills and application of strategies for information processing. (We have also located a few empirical investigations on the effect of students' conceptions or misconceptions on exploratory instruction and on

problem solving activities.) In addition, students retain these skills for a considerable period of time after their instruction. However, only high achievers may profit from complex processes of information (such as drawing conclusion or providing explanations, etc.), while grade level and IQ are important predicative factors for students' achievement when exploratory learning is being used. Inquiry-based learning in combination with active participation in experimentation renders students more receptive to science.

Hands-on activities are essential for inquiry-based science learning especially for students with learning disabilities. However, some activities should be specifically modified regarding the materials used (which is also noted by Scruggs et al., 1998). These activities may form a platform for problem solving, for students' engagement in scientific inquiry and active learning; in addition they are helpful for students with mild learning difficulties, especially when they are well structured. Hands-on activities are more effective for students when they fall either to the category "easy" or "difficult", when appropriate material has been developed and when they "place fewer demands on language and literacy abilities and verbal memory" (Scruggs et al., 1998, p. 23). In all cases, activities satisfy students more than book reading, because they consider them more interesting.

However, activities −as well as the use of laboratories− are not necessarily used in a constructivist, *exploratory learning* framework. Activities and laboratories may be used in a positivistic way, only when students verify what they have learned (i.e. confirmation type use of lab and activities). On the other hand the use of laboratories may be students-generated, if outcomes are "unknown by the students until the lab is completed" (Matkins & Brigham, 1999, p. 6). In several empirical investigations activities are part of instruction that reveals certain concepts and it is based on rules. *Hands-on* activities are generally more effective when they are part of well-structured teaching, which is circumscribed by rules and specific science concepts. Scruggs et al. (2010) mention that systematic presentation of rules through examples and repetition, followed by guided practice immediately after the completion of each part of the lesson is beneficial for students in comparison with the ones that gradually get grasp of a rule via exploratory learning and constructivism. Moreover, LD students get a better understanding of science concepts when they are engaged into inquiry-based instruction without activities rather than instruction based on unstructured activities. To sum up, students with learning and other difficulties perform better, when they are engaged in well-structured hands-on activities guided by the teacher and used in an exploratory learning context.

Following the guidelines of constructivism and exploratory learning, researchers have developed integrated *cross-curricular projects* for students with learning and other difficulties, such as Design Based Learning (Doppelt et al., 2008) and Project Based Learning (Han et al., 2015). Design Based Learning, which relates to scientific inquiry process, motivates students to solve real problems. To this end, students follow an authentic, reflective design process making use of space, materials and skills in real problems and they produce certain artifacts. LD students perform well in such projects at all the stages of the learning process except the presentation of their ideas through sketching where they encounter certain problems.

Similarly, Project Based Learning is a cross-curricular program that engages students to problem solving activities through interaction in a group and through open-ended questions. However, Project Based Learning improved students' scores in mathematics and science but not to the extent it was previously expected. Moreover, "students in the low economic status group ultimately received negative impacts from their engagement" in the Project and therefore it needs to be considered whether any particular aspect of Project "was a barrier for economically disadvantaged student's learning processes" (Han et al., 2015, p. 1108-1109).

Consequently, the use of constructivism, inquiry based instruction, well-structured hands-on activities, students-generated use of laboratories and cross-curricular projects for teaching science to students with disabilities have been extensively investigated. Therefore we consider that such topics and subtopics could be critically integrated to teacher education programs.

3.2 Multiple Means of Representation and Graphic Organizers

Several studies investigate whether presenting information and content in different ways such as converting books into hypermedia books and using *multiple means of representation* (e.g. narration, animation, comparison charts, digital maps, etc.) facilitates learning procedures or not (see Table 2). Several spatial and *graphic organizers* (such as concept maps, concept diagrams, visual aids, semantic maps, semantic feature analysis, etc.) have an overall positive effect on learning science, especially for students that encounter difficulties in writing, in understanding the content of science, and in constructing and refining cognitive schemata (See also Scruggs et al., 1998 and Scruggs et al., 2010.) The contribution of the graphic organizers to the retaining of information, knowledge and skills compared to the independent or guided study of a text has been also investigated.

Dexter et al. (2011, p. 210) in their meta-analytic review of graphic organizers argue that they "are effective not only for improving basic skills (e.g., factual recall), but also for improving higher-level skills (e.g., inference)". In science education in particular, structure of graphic organizers –and more specifically syntactic/semantic feature analysis– is suited to science content and structure, in order to help students recognize conceptual relationships, and decode science texts.

However in certain cases, when elaborated or appropriate vocabulary is required for the use of graphic organizers, the graphic depiction of the information has limited impact either on learning or on retaining the acquired information. Graphic organizers are useful only when the actual reading level of students' with difficulties has been taken into account. Therefore, teacher candidates should demonstrate knowledge of the benefits and limitations of multiple means of representation, namely graphic organizers, when they are based on language use.

3.3 Developing Cognitive and Social Skills in Students with Learning and Other Difficulties

In several investigations researchers examine how exploratory learning reinforces attention, memory and cognitive development (see Table 2). Those studies show that when students with disabilities actively construct knowledge, they encounter difficulties to "employ self-questioning strategies independently as they read from text" (Scruggs et al., 1998, p. 32), to classify information, to frame a hypothesis and draw prior knowledge. However, guided activities help students *understand* science concepts, *reach conclusions* and *form general rules by abstraction*, as well as *apply deductive thinking*. Investigators examine how teaching affects learning, when teachers use repetition, set explicit goals, present subject matter using structure, clarity, "enthusiasm, appropriate pace, and maximized engagement" (Scruggs et al., 1998, p. 28).

Activating *prior knowledge* and forming new concepts is essential for the development of cognitive skills. It is investigated how prior knowledge is activated either cognitively −when students write down relevant and irrelevant to the topic concepts− or socially −when students discuss in small groups. It is also examined how students with disabilities construct meaning based on their preconceptions, even when teachers use textbooks in a traditional approach, and how students construct meaning not merely by extracting information from reading textbooks, but rather "by relating information on the page to that already in the mind" (Parmar et al., 1994,p. 124).

A very important issue is the development of *language abilities* since students with difficulties often fail to understand science (scientific issues) due to inadequate *vocabulary*. Certain experimental interventions aim at improving students' vocabulary through adapted materials and activities, while other researchers study how exploratory learning could improve language skills, enrich LD students' vocabulary and develop their ability to use keywords. The conclusion is that LD students that get help with language issues or they have alternative means of expression available participate more in class. For example, students with problems in writing skills who presented their thoughts graphically or could use the writing skills of someone else improved their ability to express themselves.

Researchers are not only interested in students' cognitive development, but also in their *social skills'* development (see Table 2). Social skills get very important when hands-on activities are carried out, because students may display negative behaviors when teaching is not bound by rules. However, Scruggs et al. (1998) argue that hands-on activities encourage positive behavior, because students have personal motives for their engagement in the activities.

Several issues of students' personal and social development have been a matter of concern for researchers: a) *self-regulation*: techniques of self-regulation are being tested via devices that promote on-task behavior, b) *self-evaluation* and *self-appraisal* for students with difficulties: for example, a research study shows that LD students on lower classes (4th to 6th) were evaluating themselves as having lower learning abilities than students without LD, while in higher grades (7th to 8th) they were gaining self-confidence, c) *self-esteem* and *building relationships* with team members, d) *self-motivation* so as to feel happy to learn and maintain a positive attitude for the subject, etc. Investigators focus on the social skills that students develop when they need to participate in different kinds of groups.

To sum up, cognitive skills such as activating prior knowledge, comprehension, reaching conclusions and developing language abilities can be pursued when teaching science to students with difficulties. Social skills such as self-regulation or self-appraisal have not been extensively studied. However, teacher candidates could take into account that students' social skills can be pursued through peer learning, since students develop these skills when participating in groups.

3.4 Group Learning and Peer Learning

Group learning has been shown to promote active and social construction for all students. Research studies (see

Table 1) often focus on how the average students' achievements are affected when they participate in a group of students a) with difficulties, b) with learning difficulties, c) with behavior problems or d) with other students without difficulties. Researchers have also focused on students' with difficulties achievements when all members of a group are students with difficulties, or when groups consist of students both with and without difficulties (Scruggs et al., 1998). Most particularly research investigates how students with behavioral disorders are integrated in a group. According to these findings the cognitive response and performance of students without difficulties is not negatively influenced by their participation in mixed ability groups. On the contrary, these students seem to encourage LD students to apply their skills and help them whenever needed. While some studies suggest that performance of low achievers is enhanced and they comprehend better when they are involved in discussions with their peer (Scruggs et al. (2010) review) there are other findings that show that this is not exclusively due to their participation in a team. Teaching is more effective when students' participation and participation in a team is combined with hands-on activities. There are also studies that focus on how students with disabilities could get encouraged to actively participate in a team. According to these studies, LD students feel more confident to engage themselves in group discussions once they have rehearsed what they want to talk about, e.g. the description or explanation of a physical phenomenon. Special educators' support is of fundamental importance when it comes to hands-on activities in an exploratory learning context in order to aid LD students to co-operate with their peers for the social construction of concepts and peer mediations.

Therefore, teacher training programs could include issues such as the benefits of group learning strategies when teaching LD students, so that students learn to co-operate, participate and practice their social skills.

3.5 Coursebooks, Texts, Reading Strategies, Readability

The use of coursebooks has also been investigated as well as the implementation of certain reading strategies techniques and the adaptation of material at hand to LD students in comparison to traditional teaching (see Table 1). When inquiry-based learning is investigated, they mainly examine the readability of the material developed. Several research studies examine how a coursebook is used in traditional teaching as opposed to exploratory approaches or *adapted books*. The conclusion is that when the text is adjusted to the reading age of LD students (simple sentences, smaller words), their on-task behavior is extended. In other interventions, researchers adjust the texts so that thematic parts end with a concluding sentence or they re-adjust any given text by altering its structure, its length and the way information is presented in order for students to better comprehend story or science passages. Apart from researchers, teachers who have received special training co-operate in the adaption, development and production of new teaching material.

Some researchers examine the *readability* (see Table 1), the kind and number of pictures and graphics included in the coursebooks and booklets used in the labs. Other investigators examine if reading aloud, listening to a text, re-telling a story or highlighting key points improved LD students' reading ability and their ability to use any given information. Different reading techniques apply to different categories of students with disabilities. For example, a spelling program was developed for students with dyslexia who can read isolated letters while having difficulty with the structure and visually process of syllables. In this program students break down multi-syllable words into manageable chunks so as to improve comprehension of science concepts. As for expository texts, students are trained to build up their ability to trace information in a text. Another *reading* technique that is effective is to record the main idea of a text, then to list the elements presented in it and to note the sequence that these are presented (Scruggs et al., 1998; Scruggs et al., 2010).

There is also the Cover-Copy-Compare *reading technique* (Smith et al., 2002) in which LD students read a text, cover it trying to recount the information they read. In this way, researchers examine if students retain the newly acquired knowledge. Moreover, *repetitive reading technique* helps students with difficulties practice their fluency through repetition and improve their reading ability.

Phonological and morphological exercises seem to improve memory, spelling and enrich vocabulary, while hands-on activities reinforce phonological memory. Mnemonic strategies in general, are extremely effective in helping students learn words, understand terms and absorb information, but they do not contribute in more complex cognitive processes (e.g. concept comprehension) regarding the subject matter (Scruggs et al., 1998; Scruggs et al., 2010). Researchers advocate that students with difficulties are able to solve more problems and understand more concepts, when they engage themselves in group discussions as opposed to high achievers who are better in expressing their arguments through writing them down rather than orally.

Practice in modifications of instructional programs in order to respond to the needs of students with difficulties is usually included in teacher training programs. Designers of teacher education programs could also include in the

programs issues such as: reading techniques, phonological exercises, evaluation of the readability of the material developed by teachers, etc.

3.6 Students' Assessment

Students' assessment is a central topic in most studies (see Table 1), because it helps investigators evaluate the outcome of their interventions. It has to be noted though that achievements are recorded in several ways, making the comparisons of the outcomes rather difficult (Scruggs et al., 2010). Researchers use or develop assessment tools from different perspectives: they use several assessment methods, tools or techniques to evaluate students' achievement before and after the interventions, such as standard tests, questionnaires, discussions, interviews, peer-assessment, essays writing; moreover, they develop tests to examine the effectiveness of certain types of questions. They also develop new tools for diagnostic, formative or summative evaluation, which are either applied as a research tool, or are accommodated to indicators and standards set at a national or district level.

One example of developing a formative evaluation tool was the tablet that was used for self-evaluation: students with difficulties used the tablet to check their on-task behavior and in cases of attention deficit special stimulus was provided to modify this behavior. Another example of formative and summative evaluation was a computer-generated, administered and scored assessment tool, based on specific standards (such as repetitive structure), that evaluated for how long after teaching students had retained knowledge and skills. From those studies it was concluded that inquiry based instruction was more effective only when students were evaluated after a relatively long period (e.g. two weeks) while there was no difference when they were evaluated immediately after a period of traditional or inquiry-based instruction.

In general, research findings indicate that students who attend well-structured courses at an appropriate pace, from enthusiastic teachers who seek students' active engagement, achieve better outcomes. This improvement is more often demonstrated at students' portfolios and their oral evaluation, rather than in standard tests. Other studies focus on how general national standards set for assessing students' with difficulties in science are narrowed down to measurable performance indicators at a district level (e.g. state).

3.7 Teacher Training, Teacher Education, Teacher − Researcher Co-Operation

Apart from the general benefits of teacher education, investigators examine closely teachers' beliefs and attitudes (see Table 2). It is important to document how these attitudes change due to in-service training or how teachers improve their teaching material so that it is appropriate for students with difficulties. A key element for teaching improvement is the teachers' collaboration with researchers who carry out an empirical investigation in their school.

Researchers have investigated teachers' *beliefs* about planning, teaching strategies, types of questions, co-operative learning, reading strategies and students' evaluation. Moreover, they have examined how much prepared teachers feel to teach students with disabilities after their pre-service training. Several research studies focus on the *challenges* that teachers face when they use exploratory learning, and their *beliefs* and expectations from students with disabilities. It seems that LD students usually fall behind their teacher's expectations. Teachers seem more willing to change their teaching strategies and adapt teaching material for LD students or students with mental retardation rather than students with behavioral disorders. Taking into account teachers' attitudes, researchers have created a teachers training course for guided inquiry science instruction. It is indicated that teachers' attitudes and practices improved, when they participate in focus-group discussions (with their colleagues and the researchers), whose purpose is "to interpret and respond to vignettes characterizing the participation and learning of students with special needs" (Cutter at al., 2002, p. 186).

Empirical investigations also examine teachers' familiarization with the activities and teaching material adapted for students with disabilities. As expected, it is helpful when teachers are provided with a kit including all the materials (books, maps, etc.) that they will use in their courses. After they get trained they can more easily to cater for students with special needs.

Some investigators believe that teachers should be trained only to best practices and gain as much everyday class experience as possible rather than focus on theoretical knowledge during their *pre-service training*. If novice teachers get guided experience during their training in a suitable setting, they will be able to select "unconsciously" the appropriate action when facing real teaching problems. Researchers also focus on professional development seminars designed to assist teachers in their preparation to teach students with disabilities and in their familiarization with teaching strategies so that students without disabilities do not fall behind their schoolwork due to inclusive education.

Co-teaching, co-operation and *support from special education teachers* in an "inclusive setting" have also been studied (see Table 2). It is concluded that when teachers and researchers co-operate, they can jointly plan and apply

an appropriate science education program (project or curriculum) for students with learning or behavior disabilities. Teachers and research assistants formed groups that fostered structured conditions to promote co-operation and reflections on teaching. In that context teachers' ability to come up with new instructional materials and techniques suitable for their LD students and create a more elaborated instructional planning, improved.

It is evident that teacher education programs should include evidence based teaching strategies, a deep understanding of teacher candidates' attitudes towards teaching science to students with special needs, and they should enhance co-operation with special education teachers, administrative staff and researchers.

3.8 Education Policy, School Administration and Management, and Curriculum Structure

It is less frequent to locate articles on issues regarding amendments or changes in institutions, in the operation of the educational system, in education policy, school administration, curriculum structure, and other broader issues that are a prerequisite for inclusive education (see Table 2). At an institutional level, questions that concern researchers, apart from teachers education that was earlier discussed, are curriculum structure, core and non-core subjects included in it and the impact that changing levels or grades has on the achievement of students with difficulties. As far as *curriculum structure* is concerned, investigators suggest that curriculum should be structured in a way that students may attend certain non-core courses that will help them with their core courses; it is argued, for example, that "accumulating credits in technology and communication course work uniquely benefits the science course taking, and comparably benefits the math course taking of students with LD in contrast to students who are not identified with LD" (Shifrer & Callahan, 2010, p. 73-74).

A general reform −including appropriate *teacher training* and appropriate *structure of the levels of education, administrative support*, support from special educators (and co-teaching arrangements)− and an open, accepting atmosphere are generally considered essential for the application of interventions, such as those discussed above. More specifically, researchers note a decline in motivation and achievement in science, when students with difficulties *change simultaneously grade and level of education*. On the contrary, students' achievement scores are not so low when students change grade without changing grade level. Also, in the context of broader educational changes, researchers claim that low achievers improve their performance when curriculum changes come along with *teacher training* and amendments in district school policies as part of a more general reform.

Table 1. The Topics and Subtopics in the Research Papers (Part I)

Papers	Topics and Subtopics (Part I)								
	1*	2*	3*	4*	5*	6*	7*	8*	9*
Anderman, 1998									
Aydeniz et al., 2012	√	√	√		√			√	
Bay et al., 1992	√				√	√			
Bergerud et al., 1988								√	√
Berninger et al., 2008									√
Bhattacharya, 2006									√
BouJaoude & Attieh, 2008 (2008)									
Carisle & Chang, 1996									
Cawley et al., 2002			√	√				√	
Cook & Cook, 2004									
Cutter et al., 2002	√				√				
Dalton et al., 1997	√	√	√		√				
Dexter et al., 2011									
Doppelt et al., 2008			√	√					
Gaddy et al., 2008						√			√
Gebbels et al., 2010	√			√					
Griffin et al., 1991									√
Guastello et al., 2000						√			
Han et al., 2015				√					
King-Sears et al., 2014				√					
Kinniburgh & Baxter, 2012							√		√
Kirch et al., 2005									

Kostewicz & Kubina, 2011							√		√
Marx et al., 2004	√						√	√	
Mastropieri & Scruggs, 1994			√	√			√	√	√
Mastropieri et al., 1997	√								
Mastropieri et al., 1998	√		√		√		√	√	
Mastropieri et al., 1999	√		√		√		√	√	
Mastropieri et al., 2001	√	√	√						
Mastropieri et al., 2006			√		√	√		√	
McCleery & Tindal, 1999	√		√			√			
Meyer & Kenagy, 1997			√	√					
Moin et al., 2009			√		√	√			
Mumba et al., 2015	√								
Mutch-Jones et al., 2012	√		√					√	
Nolet & Tindal, 1995						√		√	
O'Leary, 2011								√	√
Palinscar et al., 2000	√				√				√
Palincsar et al., 2001	√				√			√	
Parmar et al., 1994								√	
Rivard, 2004			√		√				√
Robinson, 2002			√		√	√			√
Salta & Tzougraki, 2011		√							
Scruggs et al., 1993	√		√				√		
Scruggs & Mastropieri, 1994	√	√	√					√	
Shifrer & Callahan, 2010									
Simpkins-McCrea et al., 2009			√		√	√	√	√	
Smith et al., 2002								√	√
Spooner et al., 2008									
Vannest et al., 2011									√
Vaughn & Schumm, 1994								√	
Willis & Mason, 2014									
Wu & Tsai, 2005	√					√			

1* discovery/inquiry learning -CONSTRUCTIVISM

2* misconceptions/preconceptions-CONSTRUCTIVISM

3* hands-on activities-CONSTRUCTIVISM

4* projects/cross curricular projects-CONSTRUCTIVISM

5* group/peer learning

6* direct teaching/traditional instruction

7* traditional textbooks

8* adapting material /textbooks

9* readability/reading techniques

Table 2. The Topics and Subtopics in the Research Papers (Part II)

Papers	Topics and Subtopics (Part II)							
	10*	11*	12*	13*	14*	15*	16*	17*
Anderman, 1998			√	√			√	√
Aydeniz et al., 2012		√	√	√				
Bay et al., 1992		√		√				
Bergerud et al., 1988	√							
Berninger et al., 2008					√			
Bhattacharya, 2006								

BouJaoude & Attieh, 2008	√	√		√				
Carisle & Chang, 1996			√	√				
Cawley et al., 2002				√	√	√		
Cook & Cook, 2004					√			√
Cutter et al., 2002					√		√	
Dalton et al., 1997	√	√	√	√		√		
Dexter et al., 2011	√	√		√				
Doppelt et al., 2008		√		√		√		
Gaddy et al., 2008				√				
Gebbels et al., 2010			√					
Griffin et al., 1991	√	√		√				
Guastello et al., 2000	√	√		√				
Han et al., 2015				√	√	√	√	
King-Sears et al., 2014	√	√	√	√				
Kinniburgh & Baxter, 2012								
Kirch et al., 2005					√		√	
Kostewicz & Kubina, 2011								
Marx et al., 2004				√	√	√	√	√
Mastropieri & Scruggs, 1994	√				√	√		√
Mastropieri et al., 1997		√						
Mastropieri et al., 1998			√	√	√	√		√
Mastropieri et al., 1999			√	√	√	√		
Mastropieri et al., 2001		√		√				
Mastropieri et al., 2006	√		√	√				
McCleery & Tindal , 1999		√	√	√				
Meyer & Kenagy, 1997		√	√					
Moin et al., 2009	√				√		√	√
Mumba et al., 2015					√			
Mutch-Jones et al., 2012		√			√			
Nolet & Tindal, 1995		√		√				
O'Leary, 2011			√					
Palinscar et al., 2000	√	√	√					√
Palincsar et al., 2001	√	√		√	√			√
Parmar et al., 1994		√		√				
Rivard, 2004		√		√				
Robinson, 2002	√		√	√	√		√	√
Salta & Tzougraki, 2011		√		√				
Scruggs et al., 1993				√				
Scruggs & Mastropieri, 1994		√	√					
Shifrer & Callahan, 2010						√		
Simpkins-McCrea et al., 2009	√		√	√	√			
Smith et al., 2002		√	√	√				
Spooner et al., 2008				√	√	√	√	√
Vannest et al., 2011		√		√				
Vaughn & Schumm, 1994			√		√	√		√
Willis & Mason, 2014		√	√	√				
Wu & Tsai, 2005		√		√				

10* graphic organizers/multiple means of representation

11* developing/assessing cognitive skills

12* developing/assessing social skills

13* students' assessment

14* teacher training/ teachers' beliefs & attitudes/co-operation

15* curriculum, curriculum structure, curriculum reform-EDUCATION POLICY

16* general reforms-EDUCATION POLICY

17* administrative issues-EDUCATION POLICY

4. Discussion

From the presentation of the topics with which special education investigators have dealt, we conclude that most interventions concern the actual teaching practice (such as inquiry learning, graphic organizers, adaption of teaching material, assessment), fewer deal with teacher training issues based on the goals set by the interventions, and even fewer deal with educational policy. This presentation could potentially help researchers to determine topics and subtopics that need further investigation and higher education community to enrich teacher training programs. Similarly, education policy makers may take into consideration the aforementioned findings when they have to deal with special education issues such as the inclusion of students with special educational needs to general education.

However, "empirical support for full inclusion of all students with disabilities is unavailable" and "for some students, inclusion has been found to be harmful […] or associated with unsatisfactory results" (Matkins & Brigham, 1999, p. 25). The question of applying interventions such as those included in the empirical investigations at a wider scale is related to the problem of including students with difficulties in general education, although "inclusion of students with disabilities in general education settings should not be viewed as an either-or proposition" (Matkins & Brigham, 1999, p. 27). The issue of full inclusion is even more puzzling, when catering for students with individual differences in a classroom might slow down students without difficulties, who seek to achieve certain standards and indicators set by each country's educational system. Therefor we consider that university community, researchers and policy makers should take into account that the effectiveness of an educational system is not only based on students' scores but also on the number of students who participate in general education.

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References

Anderman, E. M. (1998). The Middle School Experience: Effects On The Math And Science Achievements of Adolescents with LD. *Journal of Learning Disabilities*, *31*(2), 128-138. http://dx.doi.org/10.1177/002221949803100203

Aydeniz, M., Cihak, D. F., Graham, S. C., & Retinger, L. (2012). Using inquiry-based instruction for teaching science to students with learning disabilities. *International Journal of Special Education*, *27*(2), 189-206.

Bay, M., Staver, J. R., Bryan, T., & Hale, J. B. (1992). Science Instruction for the Mildly Handicapped: Direct Instruction versus Discovery Teaching. *Journal of Research in Science Teaching*, *29*(6), 555-570. http://dx.doi.org/10.1002/tea.3660290605

Bergerud, D., Lovitt, T. C. & Horton S. (1988). The Effectiveness of Textbook Adaptations in Life Science for High School Students with Learning Disabilities. *Journal of Learning Disabilities*, *21*(2), 70-76. http://dx.doi.org/10.1177/002221948802100202

Berninger, V. W., Winn, W. D., Stock, P. et al. (2008). Tier 3 specialized writing instruction for students with dyslexia. *Reading and Writing*, *21*, 95-129. http://dx.doi.org/10.1007/s11145-007-9066-x

Bhattacharya, A. (2006). Syllable-Based Reading Strategy for Mastery of Scientific Information. *Remedial and Special Education*, *27*, 116-123. http://dx.doi.org/10.1177/07419325060270020201

BouJaoude, S., & Attieh, M. (2008). The Effect of Using Concept Maps as Study Tools on Achievement in Chemistry. *Eurasia Journal of Mathematics, Science & Technology Education*, *4*(3), 233-246.

Carisle, J. F., & Chang, V. (1996). Evaluation of Academic Capabilities in Science by Students With and Without Learning Disabilities and Their Teachers. *The Journal of Special Education*, *30*(1), 18-34. http://dx.doi.org/10.1177/002246699603000102

Cawley, J., Hayden, S., Cade, E., & Baker - Kroczynski, S. (2002). Including Students With Disabilities Into the General Education Science Classroom. *Exceptional Children*, *68* (4), 423-435. http://dx.doi.org/10.1177/001440290206800401

Cook, B. G., &Cook, L. (2004). Bringing Science Into the Classroom by Basing Craft on Research. *Journal of Learning Disabilities, 37*, 240-247. http://dx.doi.org/10.1177/00222194040370030901

Cutter, J., Palincsar, A. S., & Magnusson, S. J. (2002). Supporting Inclusion Through Case-Based Vignette Conversations. *Learning Disabilities Research & Practice*, *17*(3), 186-200. http://dx.doi.org/10.1111/1540-5826.00044

Dalton, B., Morocco, C. C., Tivnan, T., &Rawson-Mead, P. L. R. (1997). Supported Inquiry Science: Teaching for Conceptual Change in Urban and Suburban Science Classrooms. *Journal of Learning Disabilities*, *30*(6), 670-684. http://dx.doi.org/10.1177/002221949703000611

Dexter, D. D., Park, Y. J., & Hughes, C. A. (2011). A Meta-Analytic Review of Graphic Organizers and Science Instruction for Adolescents with Learning Disabilities: Implications for the Intermediate and Secondary Science Classroom. *Learning Disabilities Research & Practice*, *26*(4), 204-213. http://dx.doi.org/10.1111/j.1540-5826.2011.00341.x

Doppelt, Y., Mehalik, M. M., Schunn, C. D., Silk, E. & Krysinski, D. (2008). Engagement and Achievements: A Case Study of Design-Based Learning in a Science Context. *Journal of Technology Education*, *19*(2), 22-39. http:dx.doi.org/10.21061/jte.v10i2.a.2

Gaddy, S. A., Bakken, J.P., & Fulk, B. M. (2008). The Effects of Teaching Text-Structure Strategies to Postsecondary Students with Learning Disabilities to Improve Their Reading Comprehension on Expository Science Text Passages. *Journal of Postsecondary Education and Disability*, *20*(2), 100-117.

Gebbels, S., Evans, S. M., & Murphy, L. A. (2010). Making science special for pupils with learning difficulties. *British Journal of Special Education*, *37*(3), 139-147. http://dx.doi.org/10.1111/j.1467-8578.2010.00463.x

Griffin, C. C., Simmons, D. C., & Kameenui, E. J. (1991). Investigating the effectiveness of graphic instruction on the comprehension and recall of science content by students with learning disabilities. *Reading, Writing, and Learning Disabilities*, *7*, 355-376. http://dx.doi.org/10.1080/0748763910070407

Guastello, E. F., Beasley, T. M., & Sinatra, R.C. (2000). Concept Mapping Effects on Science Content Comprehension of Low-Achieving Inner- City Seventh Graders. *Remedial and Special Education*, *21*(6), 356-364. http://dx.doi.org/10.1177/074193250002100605

Han, S., Capraro, R., & Capraro, M. M. (2015). How Science, Technology, Engineering, and Mathematics (STEM) Project-Based Learning (PBL) Affects High, Middle, and Low Achievers Differently: The Impact of Student Factors on Achievement. *International Journal of Science and Mathematics Education*, *13*, 1089-1113. http://dx.doi.org/10.1007/s10763-014-9526-0

King-Sears, M. E., Johnson, T. M., Berkeley, S., Weiss, M. P., Peters-Burton, E. E., Evmenova A. S., … Hursh, J. C. (2014). An Exploratory Study of Universal Design for Teaching Chemistry to Students With and Without Disabilities. *Learning Disability Quarterly*, *38*(2), 84-96. http://dx.doi.org/10.1177/0731948714564575

Kinniburgh, L. H., & Baxter, A. (2012). Using Question Answer Relationship in Science Instruction to Increase the Reading Achievement of Struggling Readers and Students with Reading Disabilities. *Current Issues in Education*, *15*(2), 1-9.

Kirch, S. A., Bargerhuff, M. E., Turner, H., & Wheatly, M. (2005). Inclusive Science Education: Classroom Teacher and Science Educator Experiences in CLASS Workshops. *School Science and Mathematics*,*105*(4), 175-196. http://dx.doi.org/10.1111/j.1949-8594.2005.tb18157.x

Kostewicz, D. E., & Kubina, R. M. Jr. (2011). Building Science Reading Fluency for Students with Disabilities with Repeated Reading to a Fluency Criterion. *Learning Disabilities*, *17*(3), 89-104.

Marx, R. W., Blumenfeld P. C., Krajcik J. S., Fishman, B., Soloway, E., Geier, R., & Tali Tal, R. (2004). Inquiry-Based Science in the Middle Grades: Assessment of Learning in Urban Systemic Reform. *Journal of Research in Science Teaching*, *41*(10), 1063-1080. http://dx.doi.org/10.1002/tea.20039

Mastropieri, M. A., & Scruggs, T. E. (1994). Text Versus Hands-On Science Curriculum. Implications for Students with Disabilities. *Remedial and Special Education*, March, *15*(2), 72-85. http://dx.doi.org/10.1177/074193259401500203

Mastropieri, M. A., Scruggs, T. E., & Butcher, K. (1997). How Effective is Inquiry Learning for Students with Mild Disabilities? *The Journal of Special Education*, *31*(2), 199-211. http://dx.doi.org/10.1177/002246699703100203

Mastropieri, M. A., Scruggs, T. E., Mantzicopoulos, P., Sturgeon, A., Goodwin, L., & SuHsiang, C. (1998). "A Place Where Living Things Affect and Depend on Each Other": Qualitative and Quantitative Outcomes Associated with Inclusive Science Teaching. *Science Education*, *82*(2), 163-179. http://dx.doi.org/10.1002/(SICI)1098-237X(199804)82:2<163::AID-SCE3>3.0.CO;2-C

Mastropieri, M. A., Scruggs, T. E., & Magnusen, M. (1999). Activities - Oriented Science Instruction for Students with Disabilities. *Learning Disability Quarterly*, *22*(4), 240-249. http://dx.doi.org/10.2307/1511258

Mastropieri, M. A., Scruggs, T. E., Boon, R., & Carter, B. (2001). Correlates of Inquiry Learning in Science, Constructing Concepts of Density and Buoyancy. *Remedial and Special Education*, *22*(3), 130-137. http://dx.doi.org/10.1177/074193250102200301

Mastropieri, M. A., Scruggs, T. E., Norland, J. J., Berkley, S., McDuffie, K., Tornquist, E. H., & Connors, N. (2006). Differentiated Curriculum Enhancment in Inclusive Middle School Science: Effects on Classroom and High Stakes Tests. *The Journal of Special Education*, *40*(3), 130-137. http://dx.doi.org/10.1177/00224669060400030101

Matkins, J. J., & Brigham, F. (1999). *A Synthesis of Empirically Supported Best Practices for Science Students with Learning Disabilities*, Paper presented at the international Conference of the Association for Education Teachers in Science, Austin TX.

McCleery, J. A., & Tindal, G. (1999). Teaching the Scientific Method to At-Risk Students and Students with Learning Disabilities through Concept Anchoring and Explicit Instruction. *Remedial and Special Education*, *20*(1), 7-18. http://dx.doi.org/10.1177/074193259902000102

Meyer, K. A., & Kenagy, B. L. (1997). ABC-CIC: Applied Biology/Chemistry-Class in a Class: Meeting the Needs of Learning Disabled High School Students. *The Journal of Science for Persons with Disabilities*, *5*(1), 25-28.

Moin, L. J., Magiera, K., & Zigmond, N. (2009). Instructional Activities and Group Work in the US Inclusive High School Co-Taught Science Class. *International Journal of Science and Mathematics Education*, *7*, 677-697. http://dx.doi.org/10.1007/s10763-008-9133-z

Mumba, F., Banda A., & Chabalengula V. M. (2015). Chemistry Teachers' Perceived Benefits and Challenges of Inquiry-based Instruction in Inclusive Chemistry Classrooms. *Science Education International*, *26*(2), 180-194.

Mutch-Jones, K., Puttick, G., & Minner, D. (2012). Lesson Study for Accessible Science: Building Expertise to Improve Practice in Inclusive Science Classrooms. *Journal of Research in Science Teaching*, *49*(8), 1012-1034. http://dx.doi.org/10.1002/tea.21034

Nolet, V., & Tindal, G. (1995). Essays as Valid Measures of Learning in Middle-School Science Classes. *Learning Disability Quarterly*, *18*(4), 311-324. http://dx.doi.org/10.2307/1511236

O'Leary, S. (2011). The Inclusive classroom: Effect of a readability intervention on student engagement and on-task behavior within two mixed-ability science classrooms. *Science Education International*, *22*(2), 145-151.

Palinscar, A. S., Collins, K. M., Marano, N. L., & Magnusson, S. J. (2000). Investigating the Engagement and Learning of Students with Learning Disabilities in Guided Inquiry Science Teaching. *Language, Speech, and Hearing Services in Schools*, *31*, 240-251.http://dx.doi.org/10.1044/0161-1461.3103.240

Palincsar, S., A. S., Magnusson, S. J., Collins, K. M., & Cutter, J. (2001). Making Science Accessible to All: Results of a Design Experiment in Inclusive Classrooms. *Learning Disability Quarterly*, *24*(1), 15-32. http://dx.doi.org/10.2307/1511293

Parmar, R., Deluca, C. B., & Janczak, T. M. (1994). Investigations into Relationship Between Science and Language Abilities of Students with Mild Disabilities. *Remedial and Special Education*, *15*(2), 117-126. http://dx.doi.org/10.1177/074193259401500207

Rivard, L. P. (2004). Are Language-Based Activities in Science Effective for All Students, Including Low Achievers? *Science Education*, *88*(3), 420-442. http://dx.doi.org/10.1002/sce.10114

Robinson, S. (2002). Teaching High School Students with Learning and Emotional Disabilites in Inclusion Science Classrooms: A Case Study of Four Teachers' Beliefs and Practices. *Journal of Science Teacher Education*, *13*(1), 13-26. http://dx.doi.org/10.1023/A:1015177609052

Salta, K., & Tzougraki, C. (2011). Conceptual Versus Algorithmic Problem-solving: Focusing on Problems Dealing with Conservation of Matter in Chemistry. *Res Sci Educ*, *41*(4), 587-609. http://dx.doi.org/10.1007/s11165-010-9181-6

Scruggs, T. E., Mastropieri M. A., Bakken, J. P., & Brigham, F. J. (1993). Reading Versus Doing: The Relative Effects of Textbook-Based and Inquiry-Oriented Approaches to Science Learning in Special Education Classrooms. *The Journal of Special Education*, *27*(1), 1-15. http://dx.doi.org/10.1177/002246699302700101

Scruggs, T. E., & Mastropieri, M. A. (1994). The Construction of Scientific Knowledge by Students with Mild Disabilities. *The Journal of Special Education*, *28*(3), 307-321. http://dx.doi.org/10.1177/002246699402800306

Scruggs, T. E., Mastropieri, M. A., & Boon, R. (1998). Science Education for Students with Disabilities: a Review of Recent Research. *Studies in Science Education*, *32*(1), 21-44. http://dx.doi.org/10.1080/03057269808560126

Scruggs, T. E., Mastropieri, M. A., Berkeley, S., & Graetz, J. E. (2010). Do Special Education Interventions Improve Learning of Secondary Content? A Meta-Analysis. *Remedial and Special Education*, *31*(6), 437-449. http://dx.doi.org/10.1177/0741932508327465

Shifrer, D., & Callahan, R. (2010). Technology and Communications Coursework: Facilitating the Progression of Students with Learning Disabilities Through High School Science and Math Coursework. *Journal of Special Education Technology*, *25*(3), 65-74. http://dx.doi.org/10.1177/016264341002500307

Simpkins-McCrea, P., Mastropieri, M. A., & Scruggs, T. E. (2009). Differentiated Curriculum Enhancements in Inclusive Fifth-Grade Science Classes. *Remedial and Special Education*, *30*(5), 300-308. http://dx.doi.org/10.1177/0741932508321011

Smith, T. J., Dittmer, K. I., & Skinner, C. (2002). Enhancing Science Performance in Students with Learning Disabilities Using Cover, Copy, and Compare: A Student Shows the Way. *Psychology in the Schools*, *39*(4), 417-426. http://dx.doi.org/10.1002/pits.10037

Spooner, F., Ahlgrim-Delzell, L., Kohprasert, K., Baker, J., & Courtade, G. (2008). Content Analysis of Science Performance Indicators in Alternate Assessment. *Remedial and Special Education*, *29*(6), 343-351. http://dx.doi.org/10.1177/0741932507313014

Therrien, W. J., Taylor, J. C., Hosp, J. L., Kaldenberg, E. R., & Gorsh, J. (2011). Science Instruction for Students with Learning Disabilities: A Meta-Analysis. *Learning Disabilities Research and Practice*, *26*(4), 188-203. http://dx.doi.org/10.1111/j.1540-5826.2011.00340.x

Vannest, K. J., Parker, R., & Dyer, N. (2011). Progress Monitoring in Grade 5 Science for Low Achievers. *The Journal of Special Education*, *44*(4), 221-233. http://dx.doi.org/10.1177/0022466909343121

Vaughn, S., & Schumm, J. S. (1994). Middle School Teachers' Planning for Students with Learning Disabilities. *Remedial and Special Education*, *15*(3), 152-161. http://dx.doi.org/10.1177/074193259401500303

Willis, H. P., & Mason, B. A. (2014). Implementation of a Self-Monitoring Application to Improve On-Task Behavior: A High-School Pilot Study. *Journal of Behavioral Education*, *23*(4), 421-434. http://dx.doi.org/10.1007/s10864-014-9204-x

Wu,Y.-T., & Tsai, C.-C. (2005). Development of Elementary School Students' Cognitive Structures and Information Processing Strategies Under Long-Term Constructivist-Oriented Instruction. *Science Education*, *89*(5), 822-846. http://dx.doi.org/10.1002/sce.20068